United States Patent [19]

Sluyter et al.

[11] Patent Number: 4,600,938

[45] Date of Patent: Jul. 15, 1986

[54] FOCUSABLE VIDEO CAMERA FOR USE WITH ENDOSCOPES

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[73] Assignee: **Circon Corporation**, Santa Barbara, Calif.

[21] Appl. No.: **578,106**

[22] Filed: **Feb. 7, 1984**

[51] **Int. Cl.⁴** **H04N 7/18**

[52] **U.S. Cl.** **358/98**; 358/229

[58] **Field of Search** 358/98, 901, 213, 209, 358/229; 128/4–11

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[57] **ABSTRACT**

A highly compact focusable video camera for use in medical and surgical procedures in conjunction with an endoscope is shown. The focusable video camera includes a two-part body having a first body portion having an optically apertured forward end portion thereof and a cylindrical sidewall, a second body portion having a rearward end portion and a cylindrical sidewall wherein the first and second body portions are slidable one into the other and having portions of their respective cylindrical walls overlapping. A coacting member is located on the overlapped portion of the cylindrical wall of each body portion and causes relative forward and rearward axial motion of the body upon rotation of one body relative to the other. The body portions define a cavity having an optical aperture which defines an optical axis extending through the optical system and outside the body for receiving and transmitting optical images received from the endoscope. The optical system includes a forward portion mounted on the first body portion and a rearward portion located on the second body portion and a sensor-converter which receives and converts the optical image to an unprocessed video signal and a video electronic processing circuit in the cavity extending around the outside of the rearward portion of the optical system.

7 Claims, 10 Drawing Figures

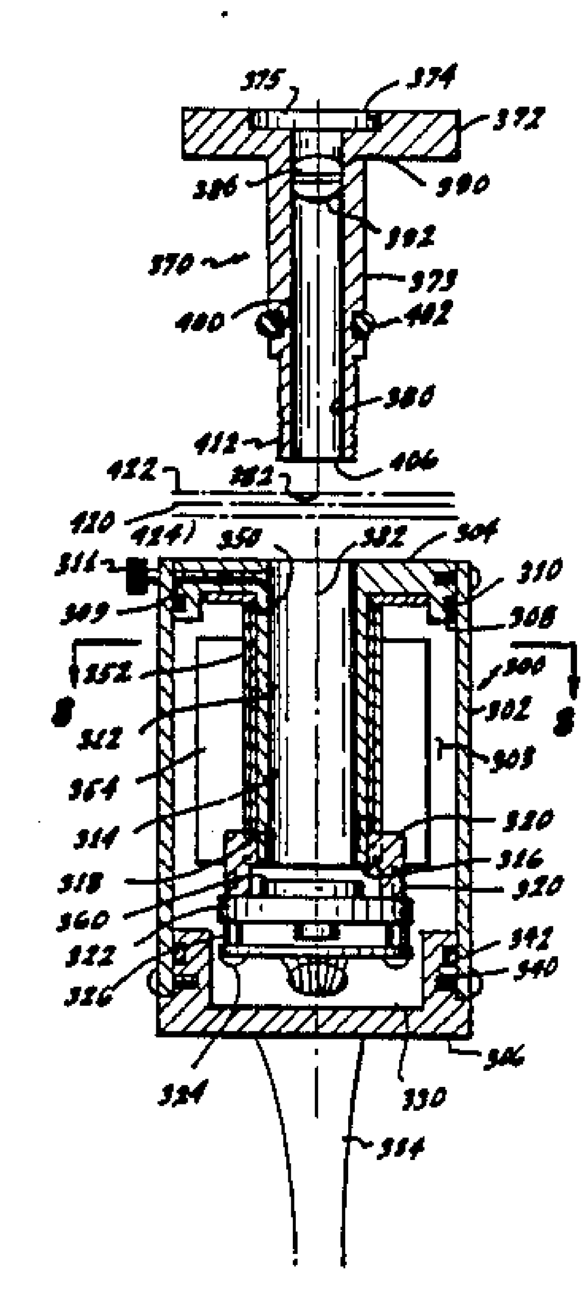


FIG. 1

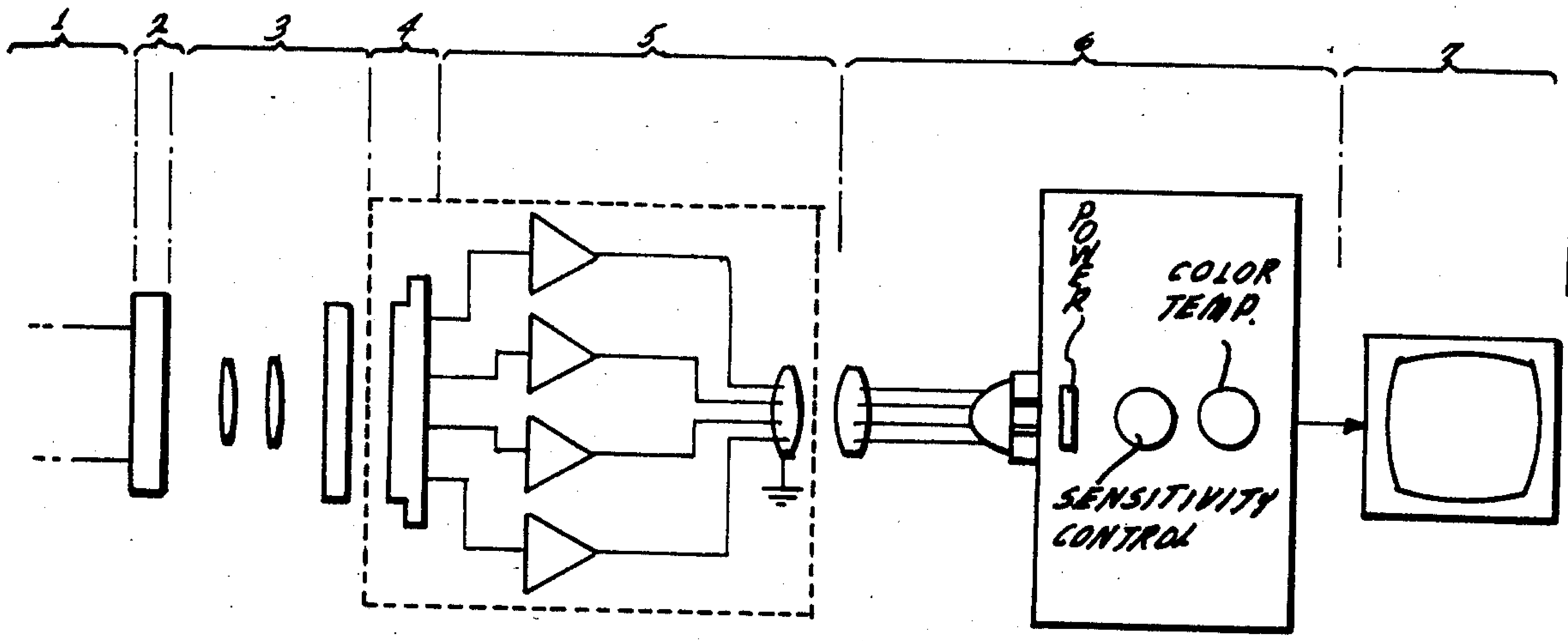
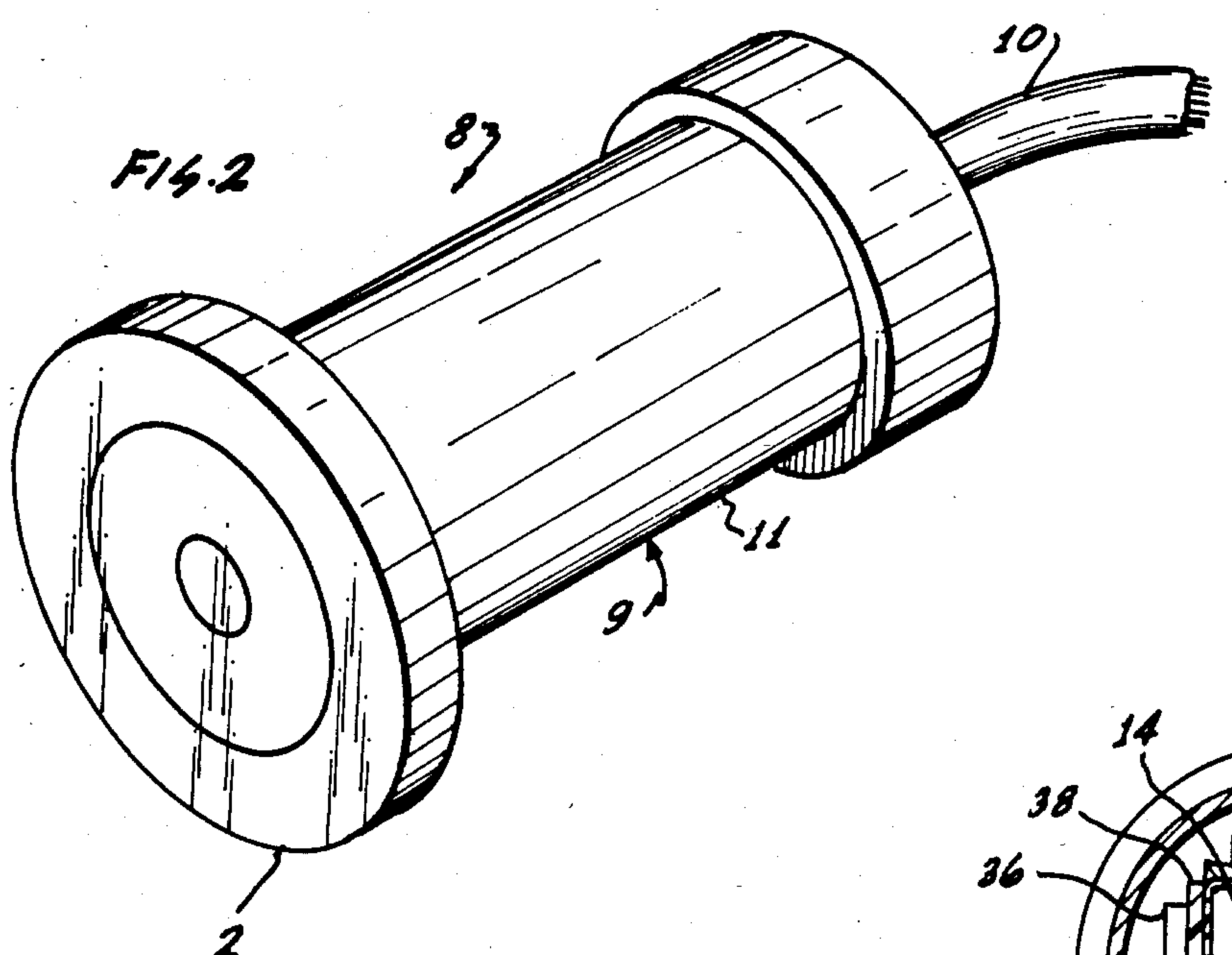


FIG. 2



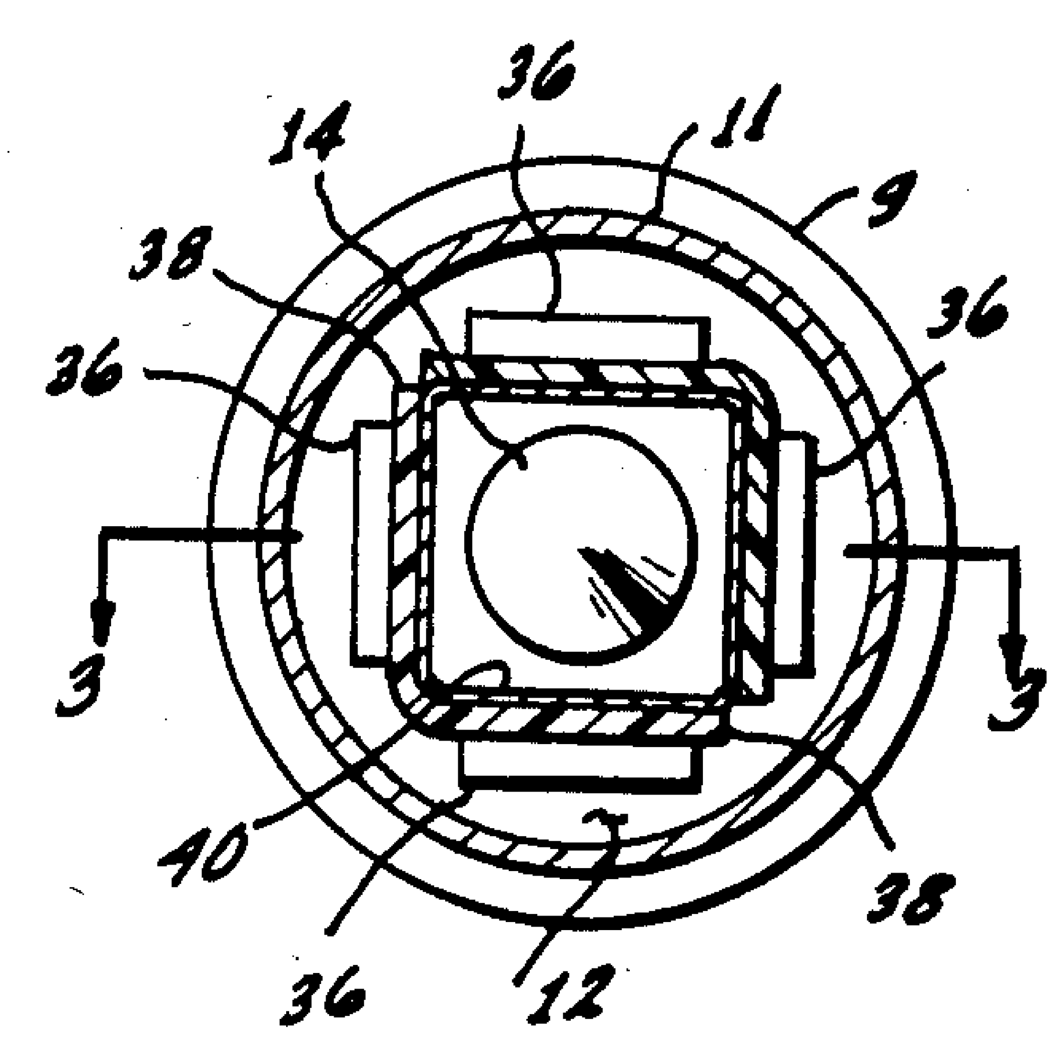


FIG. 4

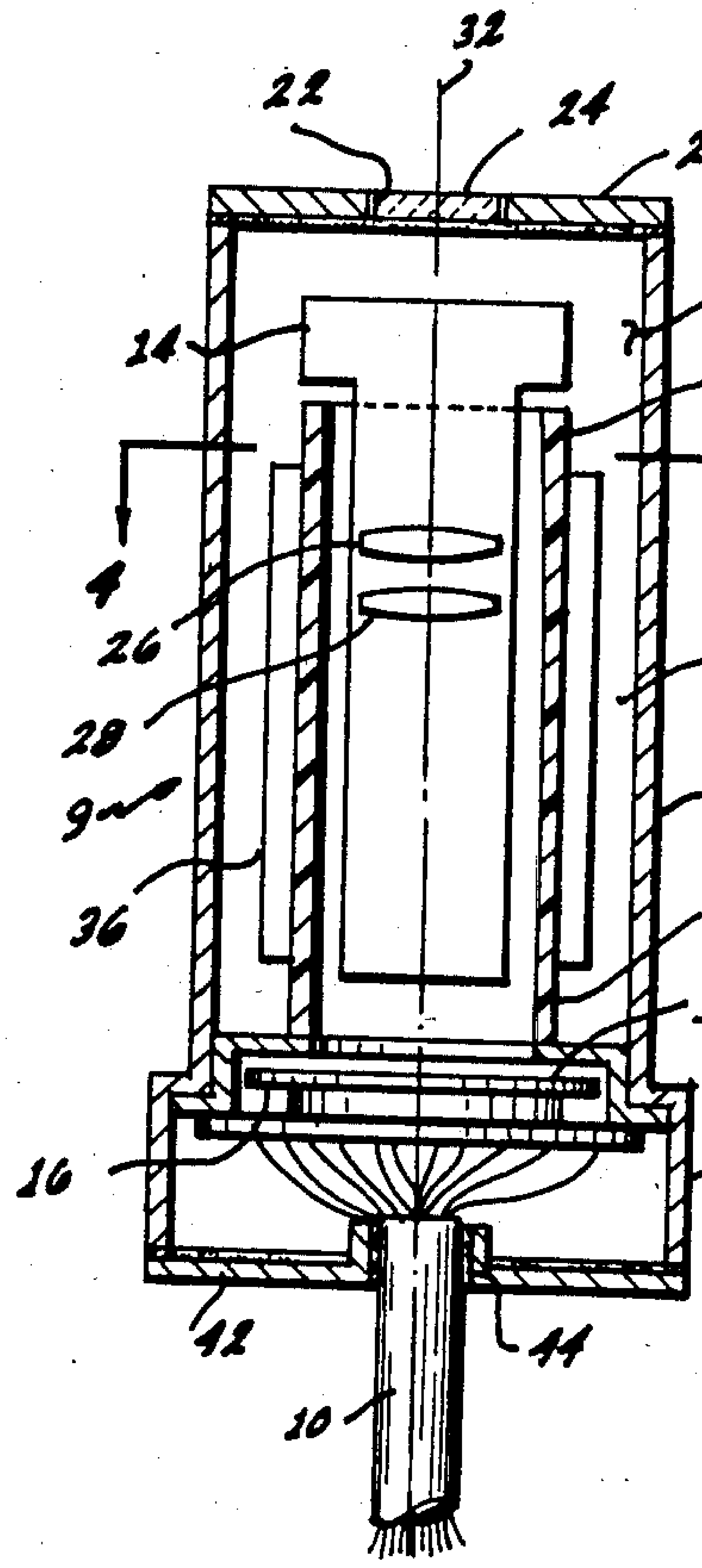

32
22
24
20
12
14
18
4
4
26
36
28
9
11
36
38
34
16
30
42
44
10

FIG. 3

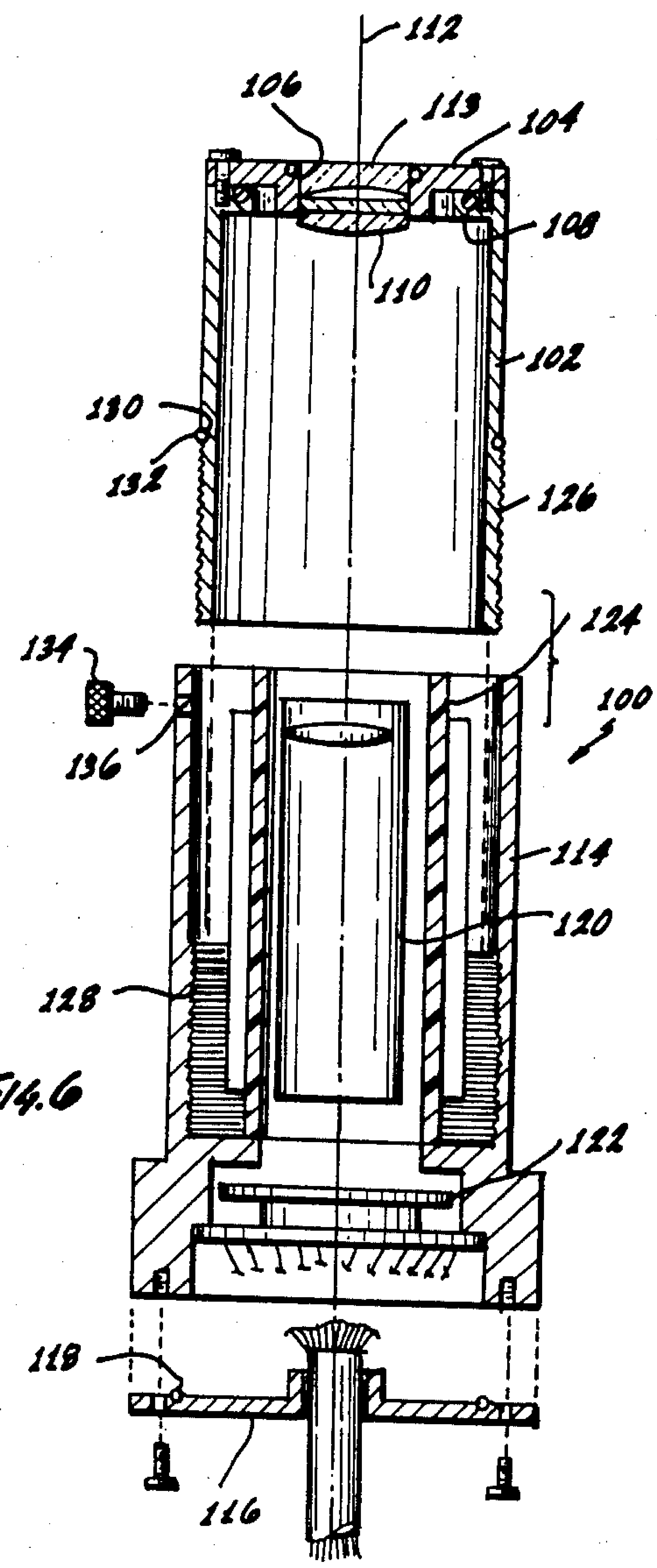

112
106
113
104
108
110
102
130
132
126
124
134
100
136
114
120
128
122
118
116

FIG. 6

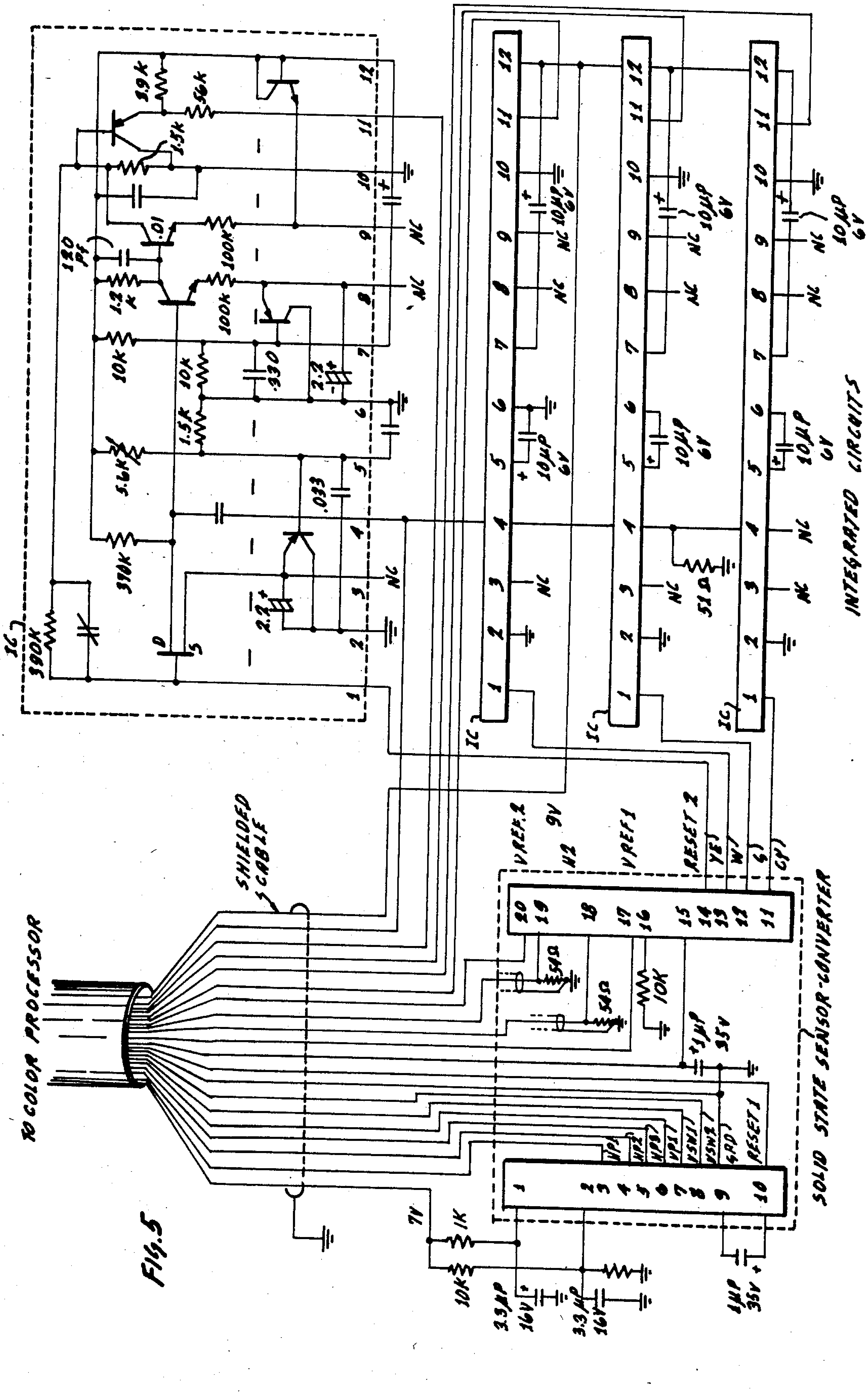
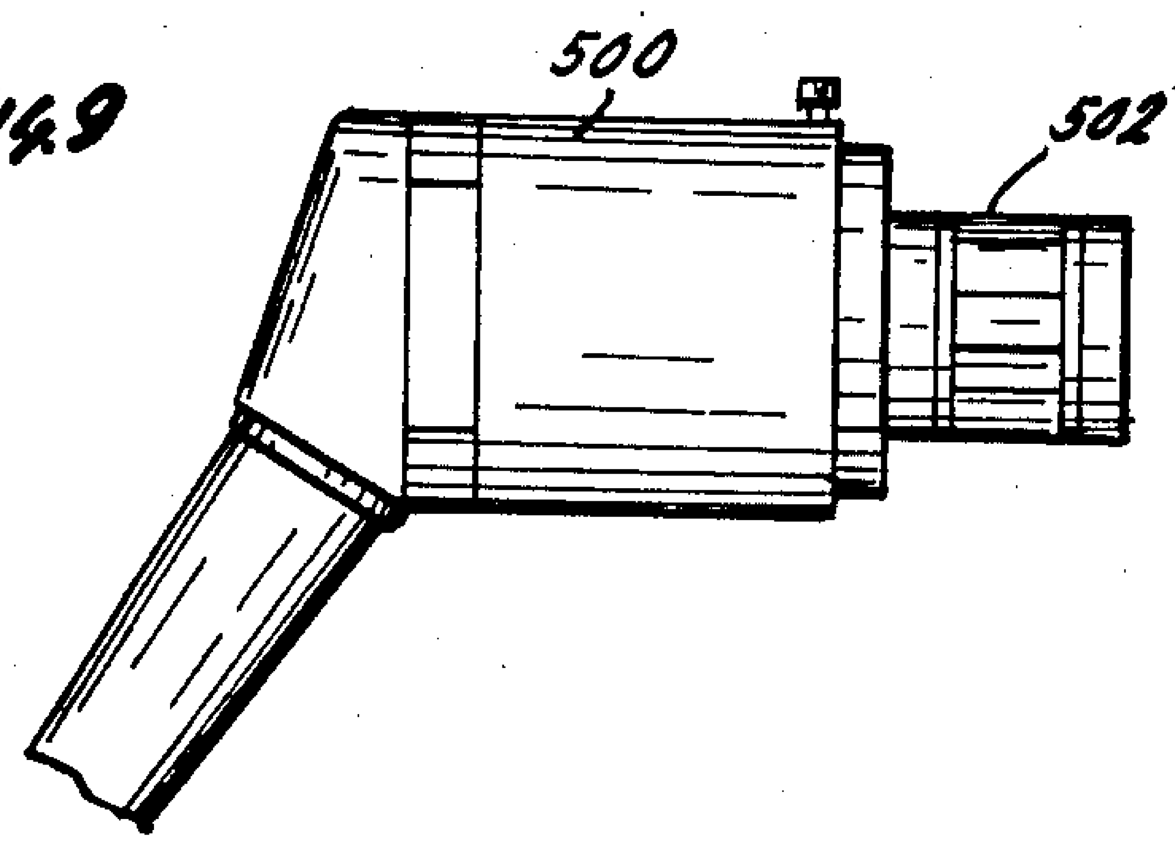

TO COLOR PROCESSOR
SHIELDED CABLE
INTEGRATED CIRCUITS
SOLID STATE SENSOR-CONVERTER
IC
NC
RESET 2
RESET 1
VREF 1
VREF 2
10μF 6V
10K
1K
3.3μF 16V
1μF 35V

FIG. 5

FIG. 9



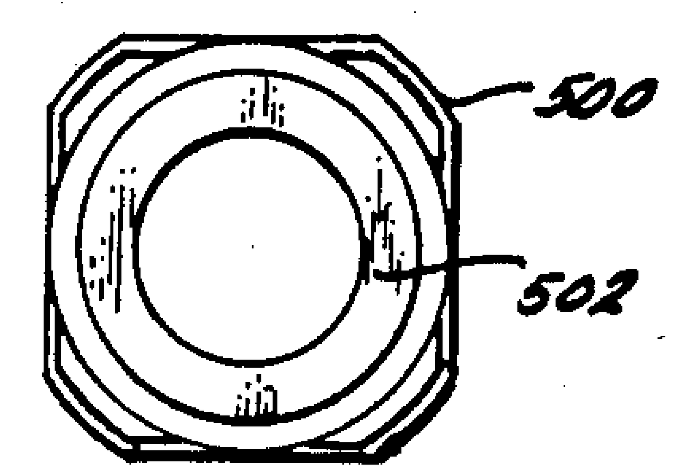


FIG. 10

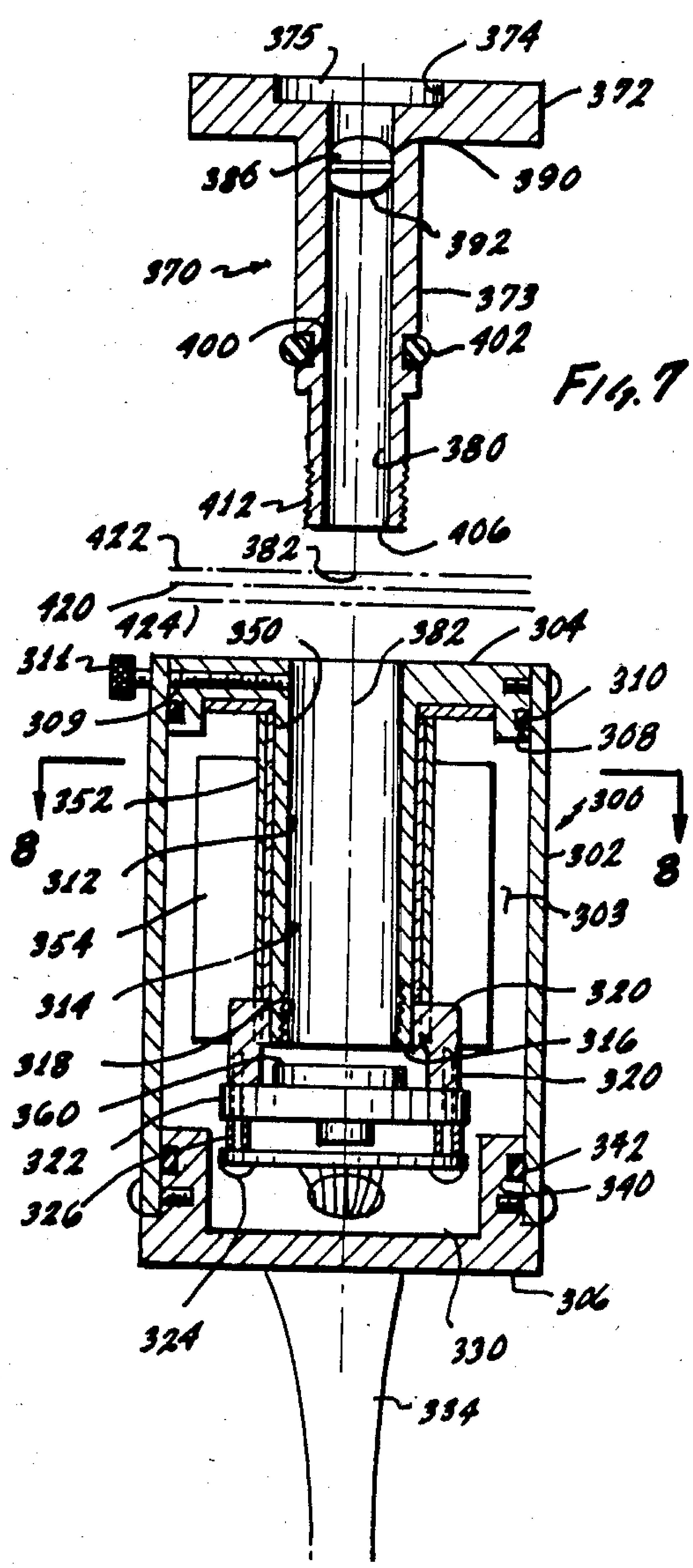
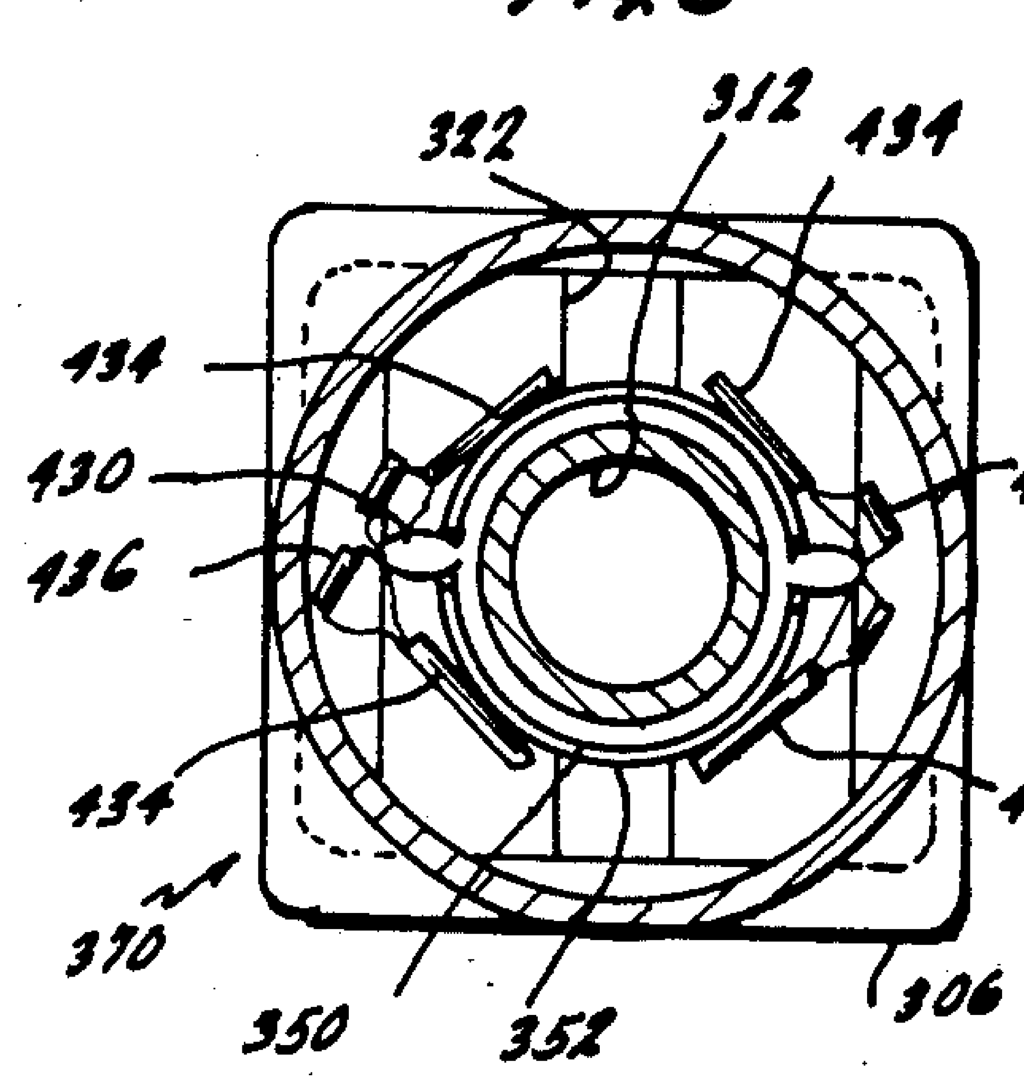


FIG. 7

FIG. 8



FOCUSABLE VIDEO CAMERA FOR USE WITH ENDOSCOPES

BACKGROUND OF THE INVENTION

This invention relates to video cameras for use in conjunction with endoscopes in medical and surgical applications. In particular, the invention relates to video cameras which are or may be attached to the end of the endoscope operated by medical personnel where an image from a selected area inside a patient's body cavity is produced external to the endoscope.

Endoscopes have established a wide variety of utility in the medical and surgical fields for viewing inside the human body. For example, endoscopes are useful in the surgical specialties of arthroscopy, bronchoscopy, colonoscopy, cystoscopy, gastroscopy, laparoscopy, laryngoscopy, sigmoidoscopy, microsurgery, neurosurgery, colposcopy, ophthalmology/corneal surgery with microscope, ophthalmology/vitreous surgery with microscope, and ophthalmology/indirect examination and general surgery. In typical applications, the forward end of an endoscope is placed in the body cavity where viewing is desired. An illumination means is provided either as part of the endoscope or by a separate means. The endoscope end senses imagery in the cavity and transmits that imagery, typically by means of a fiber optic bundle to an output means at the end of the endoscope outside the body. The light signals delivered at the output end of the endoscope are then employed in a variety of ways, such as by direct viewing or through beam splitting by both direct viewing and to a camera for television viewing or by television viewing alone. Where it is desired to televise the endoscopy, the features desired in the camera are complex due to the large performance differences in different types of endoscopes, the reduced light transmission of endoscopes with age, the wide variety of light sources, the variation of type of cavity into which the endoscope may be inserted and the need for ease of handling and light weight to facilitate use. Light transmission is a key variable among endoscopes. The type and size of endoscope greatly affects the amount of light transmitted from a subject to the television camera. For example, larger glass fiber bundles yield more light, hence, a brighter image which is easier to televise. The outside diameter of endoscopes of the same type may be an indication of the size of the glass fiber bundle. In general, shorter and larger diameter endoscopes transfer more light than longer or smaller diameter instruments. Operating endoscopes usually have smaller light transmission bundles than diagnostic types to permit channels for instruments, air, and/or water. Thus, it is usually easier to televise imagery from diagnostic endoscopes than from operating endoscopes, given the same medical circumstances.

Light transmission of fiber optic bundles in an endoscope declines with age. Also, usage tends to break individual fibers, reducing the amount of light transmitted. Exposure to heat gradually yellows the fibers, degrading light transmission and distorting the color. High usage endoscopes, therefore, requires brighter light sources or increased camera sensitivity for satisfactory television viewing. For maximum light transmission, an endoscope should have clean optics and light channels. It is important that the camera-light-source combination used in endoscopy provides sufficient sensitivity and intensity to produce a satisfactory color television image. Manufacturers of endoscopes offer several light sources having a great range of intensity. In selecting a light source, it is important to consider the viewing media in that television viewing requires a more brightly lit subject than direct ocular viewing. A common endoscopy problem is the dramatic reduction in image intensity resulting when the endoscope moves from a small body passage into a much larger cavity. In a small passage, there may be more than adequate illumination for a distance from the endoscope tip to the subject, for example, up to 20 millimeters. However, when the endoscope enters a larger cavity, the subject distance may increase, for example, up to 100 millimeters or greater. At 100 millimeters, the light on the subject is reduced by the inverse square of the subject distance to about 4 percent of the light available at 20 millimeters. In addition, the relative angle of the tissue to be viewed may change, altering the reflectivity of the surface. Further, small diameter cavities often act as a reflector directing light forward toward the viewing area.

Typically, for viewing video endoscopy, a 12-inch television monitor is satisfactory. The size of the image on a particular monitor is determined by the magnification of the endoscope. Image size as a percentage of screen height is important from the standpoint of brightness and resolution. As the image is enlarged to full screen height, the image resolution will increase because more video scanning lines are utilized. However, image brightness decreases as a function of the square of image size. With constant illumination and no light change, a 40 percent larger image will be 50 percent less bright.

A number of video cameras for endoscopy have been available. For example, a color television endoscope camera is made by Circon Corporation, Model MV 9330/35. This camera weighs 6 ounces and employs a pick up tube two-thirds of an inch in length. Also, Circon Corporation has had available various optical accessories, including couplers, eye piece adapters, and beam splitters. The resulting video system is sufficiently small and light that it can be mounted directly on any rigid or flexible endoscope. Since the color television camera receives a direct image from the endoscope, its image brightness, color fidelity, and resolution are superior to larger size cameras, which must be connected to an endoscope through articulated lenses or fiber optic links. Moreover, such links can cause image rotation and waste valuable image intensity, thereby interfering with the endoscopy process. For the interface of a video camera to an endoscope, an optical coupler is normally employed. The coupler connects the camera directly to the endoscope. Thus, all the available light goes directly into the camera, permitting the brightest possible television image. However, it is also possible to interpose a beam splitter between the endoscope and the camera optics for direct viewing as well as video monitor viewing. Furthermore, it is common to apply an adapter ring to the endoscope for easily removing the video camera or the beam splitter when used, thus providing direct viewing to the endoscope.

All video cameras compensate for some range of light level. However, that range is frequently exceeded when viewing tissue at varying distances from the distal tip of the endoscope and varies as a function cavity size. The result is washed out or darkened images. It can be seen that size, weight, and sensitivity are important features of video cameras for use in conjunction with endoscopes. The aforementioned Circon Corporation Model MV 9330/035 camera, for example, is 1 ½ inches in diameter by 5 ½ inches long and weighs six ounces. Another camera, also made by Circon Corporation, is Model MV 9320/25, which has particularly low light level sensivity, being about 10 times more light sensitive than any other color television endoscope camera. This camera is 1 ½ inches in diameter by 5 ½ inches long and weighs also six ounces. Its unique light sensitivity is particularly advantageous in televising very difficult microsurgery. The above-described devices are employed first by use of an adapter fixed to the end of the endoscope which receives an optical coupler having therein an optical system for passing the image to the camera. At the end of the coupler, a camera is attached. The coupler-and-camera combination receives optical imagery from the output end of the endoscope and converts it to preprocessed color video signals which are then transmitted for processing and projection on a color television monitor.

Although a high degree of miniaturization has been made possible by advances in the manufacture of electronic components and circuitry, and substantial light weight has been made possible similarly by advances in materials sciences, it is, nevertheless, very desirable to further reduce the size and weight of the entire endoscope video system, particularly that portion of the system which is directly attached to the end of the endoscope and which must be handled by medical personnel.

SUMMARY OF THE INVENTION

The method of the present invention for manufacturing a video camera for use in conjunction with an endoscope provides for forming a hollow body and enclosing within the body an optical system for receiving and transmitting optical imagery from an endoscope and placing around the outside of the optical system, but within the same body, electronic circuitry for preprocessing video signals received from a sensor-converter located within the body and behind the optical system. The apparatus of the invention is that resulting from the foregoing method.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other advantages of this invention will become apparent from the following description of the preferred embodiments when considered together with the accompanying drawings, which include the following figures:

FIG. 1 is a diagram of a video system which employs the invention;

FIG. 2 is a perspective view of the outside of the camera of the present invention along with an adapter for facilitating attachment to an endoscope;

FIG. 3 is a lengthwise section view through the optical axis of the optical system, along line 3—3 of FIG. 4;

FIG. 4 is a sectional view through line 4—4 of FIG. 3;

FIG. 5 is the electronic circuit of the camera; and

FIG. 6 is a sectional view of an alternative embodiment of the invention;

FIG. 7 is a sectional view of an alternative embodiment of the invention;

FIG. 8 shows the processor of the embodiment of FIG. 7;

FIG. 9 and FIG. 10 illustrate yet another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows a general diagram of an endoscope video system comprising the output end of an endoscope 1, and adapter 2 for connecting the endoscope 1 to an optical system 3, a solid state sensor-converter 4 which receives light from the optical system 3 and converts it in a known manner to electronic signals capable of being further processed for video display, the sensor-converter 4 being connected to driver-preamplifiers of the preprocessing electronics 5, whose output signals are transmitted to the processing electronics 6, and finally the video signals are transmitted to the video monitor 7. With this general description of an endoscope video system in mind, the subject of the present invention can be fully described.

In FIG. 2 there is shown an external view of the camera 8 of the present invention comprising a body 9 and, attached to it, an adapter 2 for attaching the camera 8 to an endoscope. The adapter 2 is of a conventional known design. Also, a cable 10 is shown extending from the most rearward portion of the body 9 and will normally extend to a video processing system for processing and projecting video signals onto a video monitor.

As shown in FIGS. 2 and 3, the endoscope video camera of the present invention is made up of a body shown generally at 9, which is adapted for containing and having mounted therein the various components of the camera. In particular, the body 9 has a main cylinder portion 11 which defines a cavity 12, in which are mounted the three subsystems of the camera, namely, the optical lens system 14, the sensor-converter 16, and the preprocessing electronics 18.

The body 9 has a forward end 20 which has an aperture 22. The aperture 22 is sealed and covered by a window 24. The optical lens system 14 is aligned behind the aperture 22 and is illustrated by lenses 26, 28 and 30, defining an optical axis 32. Although the window 24 and simple lenses 26, 28 and 30 are here illustrated, a more complex system, including one in which the window 24 would be used as a lens, could be employed in a manner known to those skilled in the art.

The sensor-converter 16 has a receiving surface 34 which is a self-scanning solid state imaging device, such as a charge coupled device the F(CCD) or a MOS device located in image plane of the lens system 14, and mounted in a slightly enlarged, cylindrical portion 30, of the body 9, rearward of the main cylinder portion 11. The specific construction and operation of such a MOS imager is known to those skilled in the art and is exemplified by the Hitachi Model HE 98221. The preprocessing electronics 18 are operatively connected, in a known manner, to the sensor-converter 16.

The preprocessing electronics 18 include four integrated circuit packages 36, one to process each of the color signals—yellow, white, green, and cyan. Such integrated circuits are well known in the art. The integrated circuit packages 36 are mounted on printed wiring substrates 38 which are arranged around the outside of the lens system 14, extending inside the main cylinder portion 11 and mounted to the body 9. Thus, the lens system 14 and the preprocessing electronics 18 effectively occupy the same space within the body 9. This results in considerable savings and improvement over prior devices in both size and weight. The printed wiring substrate **38** is made in a known manner according to the required circuit from flexible, plastic material. The printed wiring substrate extend around the lens system **14**.

In FIG. **4**, two separate substrates, which could be relatively rigid with a flexed or bent corner portion, are shown. Also, the substrate could be one piece of flexible-type circuit positioned around the lens system with flat areas upon which the integrated circuit packages **36** are mounted. In order to maintain the printed wiring substrate **38** and its accompanying integrated circuit (IC) packages **36** in place and separated from the optical lens system **14**, it is desirable that a substructure, such as illustrated at **40**, be placed beneath the substrate. As an example of such substructure **40**, material known as "fish-paper" folded into a generally square shape may be employed. Further, the printed wiring substrate **38** rests inside the body **9** upon a shoulder inside the cavity **12** where additional mounting means may be employed to retain the circuit in a fixed position.

Rear enclosure **42** closes the rear of the body **9**. Rear enclosure **42** has an aperture **44** through which cable **10** sealably passes. The cable **10** carries wires operatively attached to the electronic means within the body carrying video signals to a color video processor at a remote location and thereafter to a video monitor and includes means for providing power to operate the internal electronics. A sealing means, illustrated in FIG. **6** as a circular ring seal, such as an O-ring, seals the rear enclosure **42**, where it attaches to the cylindrical portion **11**. Also, the forward end **20** may be formed as a separate sealable cover, similarly employing a sealing means as illustrated in FIG. **6**, by an O-ring seal. Use of a separate sealably attachable forward end **20** and rear enclosure **42** is preferred for simplicity of manufacture of the body **9**. It is an important feature of the camera that the optics and electronics are carried in a single-body portion in a very compact manner so that the optics and preprocessing electronics reside in the same part of the body, effecting dual use of that part of the body and eliminating the need for separate parts. Also, this combined optical and electronic camera structure is easily sealable to be soakable in disinfectant for medical purposes, which is accomplished by the sealable features of both the rear enolosure **42** and the forward end **20** which is more fully described with reference to FIG. **6**.

In FIG. **5**, the electronic circuit of the camera is converter **16** and the integrated circuits **36**. Where component values are shown in FIG. **5**, capacitor values are in microfarads and resisters in thousand ohms, except as otherwise noted. The circuit of the four integrated circuits **36** are the same, one of them being shown in detail.

In use, the camera of the present invention has placed on its front end an adapter **2**, of known design, as shown in FIG. **1**, which is then attached in a known manner to the receiving end of an endoscope or, alternatively, to the receiving end of a beam splitter, which is attached to the receiving end of the endoscope.

The manner of operation of the present camera is well known to those skilled in the art and, therefore, need not be described herein in detail. In general, optical imagery transmitted through the endoscope to its output end passes through the window **24** and is transmitted through the optical lens system **14** to impinge upon the receiving CCD grid pattern of the sensor-converter **16**. Electrical signals from the sensor-converter **16** are transmitted through appropriate wiring to the preprocessing electronics **18** and thereafter through interconnected wiring to the cable **10** to connect to a color video system in a remote location. The sensor-converter **16** is activated and controlled by means of interconnections through the cable **10** and from the preprocessing electronics **18**.

An alternative embodiment of the invention is shown in FIG. **6**, which includes all the advantages of the invention as previously described but has the additional feature that the optical system is focusable. In this embodiment, the body **100** is formed of two parts. The first body portion **102** is a cylinder which retains a forward portion **104**, which has in it an optical aperture **106**. The forward portion **104** is sealably attached to the first body portion **102** by means of seal **108**. A forward portion of the optical system **110** is attached to the first body portion **102**, aligned with the optical aperture **106** defining an optical axis **112**. As previously mentioned, the aperture **106** is covered by a window **113**, which could also be part of the optical system. A rearward second body portion **114** is also in the form of a cylinder and retains the rear closure **116**, sealed by means of the seal **118**. The first body portion **102** is telescoped inside the second body portion **114**.

Mounted inside the second body portion **114** is a rear portion **120** of the optical system. The sensor-converter **122** and the preprocessing electronics **124** are shown mounted in and are connected in the second body portion **114** in a manner similar to that hereinbefore described. On the outer periphery of the cylindrical first body portion **102** is a thread **126**, and on the inner periphery of the second body portion **114** is a thread **128**, the threads **126** and **128** being interengageable so that relative rotation of the first body portion **102** and the second body portion **114** will cause relative movement of the forward portion **110** and the rearward portion **120** of the optical system to accomplish focusing.

The telescoped cylindrical parts of the body portions **102** and **114** should be sized for close but freely movable fit. For sealing, a groove **130**, in the first body portion **102** contains an O-ring seal **132**. A set screw **134** in a threaded hole **136** acts to retain the two body portions in position to maintain the focus of the optical system.

This alternative embodiment operates in the same manner as previously explained. However, it provides the additional feature of focusing the image at the image plane. The sensing base of the sensor-converter **122** is preferably located at the image plane.

FIG. **7** illustrates an alternative embodiment of an endoscope camera using the teachings of this invention. The body is shown generally as **300**. The cylindrical body **302** has a cavity **303** which is adapted to receive a top member **304** and a bottom member **306**. Top member **304** includes an annular slot **308** which is adapted to sealingly receive an O-ring **310**. The top member **304** includes a thin-walled, elongated, cylindrically shaped, tubular member **312** which extends a predetermined length into the cavity **303**. The top member **304** includes a threaded hole **309** for accepting extended locking member **311**.

The interior sidewall **314** of the tubular member **312** has located near its termination in the cavity at **316** internal threads **318**. At its termination in the cavity, there is located on the exterior sidewall of the tubular member **312** a pair of opposed elongated finger-like supports **320** for spacing the end **316** from a solid-state imaging device **322** which is attached by fasteners **324** through spacer **326** to the supports **320**.

The bottom member **306** includes a recessed area **330** which accommodates the electrical conductors **332** from cable **334**. The bottom member **306** likewise includes an annular slot **340** for receiving a sealing O-ring **342**.

In addition, an assembly formed of two concentric cylinder-shaped members **350** and **352** which are formed of copper and Delrin, respectively, installed concentrically on tubular member **312** are part of a video processing means and are utilized for supporting the video processing electronics shown generally as **354**. The details of the assembly comprising the video processing means is shown in FIG. **8**.

As is shown in FIG. **7**, the central area of the tubular member **312** provides an optical path for an optical image which is to be focused on the sensing face **360** of the solid-state imaging device **322**. In the preferred embodiment, the solid-state imaging device **323** is an MOS sensor.

An adapter member, shown generally by **370**, includes a circular top member **372**, having a recess **373** to define an optical aperture. A tubular, elongated, thin-walled support member **370** having an elongated central area **380** communicates with optical aperture **374**, to define an optical path which extends along the longitudinal axis of the circular top member **372** illustrated by dashed line **382**. A transparent element **375** is fitted in recess **374**.

An optical system **386**, formed of achromatic lens element **390** and **392**, is adapted to pass an optical image from an endoscope (not shown) which enters through window **374**, along the optical path and defining an optical axis **382**.

The tubular member **370** includes an annular slot **400** which receives an O-ring **402** which is adapted to sealingly, slidingly move on the interior wall **314** of the elongated tubular member **312**.

The interior end **406** of elongated member **370** has threads **412** formed on the exterior wall of elongated member **378**. The threads **412** are adapted to coact with threads **318** when the adapter **370** is inserted into the body **300**.

The threads **412** and **318** cooperate and coact with each other to enable relative rotatable movement between adapter **370** and body **300** such that the focal plane of the optical system **386** can be adjusted as illustrated diagramatically by focal plane lines **420**, **422** and **424**, within the body **300**. In use, the adapter **370** is rotatingly mounted within the body **300** and rotatable therewith to focus the optical image, located at the focal plane, onto the imaging surface **360** of the solid-state imaging device **322**.

FIG. **8** shows in section that the body **302** is cylindrical in shape with the bottom member **306** being rectangular in shape.

The video processing means include the copper cylindrically shaped member **350** and a Delrin cylindrically shaped member **352**, concentrically mounted thereon and concentrically mounted on the tubular member **312** to form an inner copper conductive support member and Delrin insulating member. The Delrin insulating member has a plurality of apertures or slots formed therein through which elongated conductive terminals **430** extend from the copper member **350**. Integrated circuit devices, shown generally **434**, are mounted in the assembly along with other electrical components, shown generally as **436**, and are electrically connected to each other and to the elongated conductive terminals **350** in a correct circuit manner. Thus, the preprocessing electronic circuit is arranged around the periphery of the focusable optical system, and continued in the same body portion as the optical system, forward of the solid-state imaging device.

FIG. **9** and FIG. **10** illustrate yet another embodiment for practicing the invention. The adapter top member **502** is shown attached to the body, shown generally as **500**. The top member **502** includes a bayonet-type swivel which enables the endoscope camera to be attached to an endoscope having a bayonet receiving means. The remaining portion of the body **500** and its contents are generally of the construction discussed hereinbefore.

The descriptions and illustrations herein show a cable as the conducting or transmission means. However, the conducting means or transmitting means may be a radio frequency telemetering system having an appropriate power source, transmitting means and receiving means. Such a system would eliminate the need of a cable.

The endoscope conveying the optical image to the video camera could be fabricated such that the end of the endoscope could be directly affixed to or operatively adjacent to the surface of the solid-state imaging device inside the body of the camera. An alternative position of the end of the endoscope would be to locate the end thereof at the outside end of the adapter at the point of a coupling plane between the endoscope and adapter or, if so designed, spaced from the end of the adapter.

Also the optical system can have a folded optic path having a single or multiple prism or include some other similar type of optical deflecting or splitting means located along the optical path. Thus, the embodiment of FIG. **7** is merely exemplary and one configuration of the optical path.

While this invention has been explained with reference to the structure and method disclosure herein, it is not confined to the details as set forth, and this description and the following claims are intended to cover any modifications or changes that may come within the scope of the claims.

What is claimed is:

1. A highly compact focusable video camera for use in medical and surgical procedures in conjunction with an endoscope comprising:

a two-part body comprising:

- a first body portion having an optically apertured forward end portion and a cylindrical sidewall; and
- a second body portion having a rearward end portion and a cylindrical sidewall;

the first and second body portions being slidable one within the other and having portions of their respective cylindrical walls overlapping;

coacting means on the overlapped portion of the cylindrical wall of each body portion to cause relative forward and rearward axial motion of the body portions upon rotation of one body portion relative to the other;

the body portions defining a cavity;

an optical system inside the cavity aligned with the optical aperture to define an optical axis extending through the optical system and outside the body for receiving and transmitting optical endoscope imagery;

the optical system comprising:

a forward portion mounted on the first body portion; and

a rearward portion mounted on the second body portion;

a sensor-converter operatively placed inside the cavity to receive optical imagery passing through the optical system for converting the optical imagery to unprocessed video electronic signals; and

video electronic preprocessing circuit means in the cavity adjacent the optical system;

whereby the optical system may be focused by relative rotation of the first and second body portions.

2. The apparatus of claim **1** further comprising:

seal means between the cylindrical walls of the first and second body portions to seal the cavity against entry of fluid upon soaking.

3. The apparatus of claim **2** further comprising:

releasable holding means coacting between the first and second body portions for selectively fixing the position of the forward and rearward portions of the optical system.

4. The apparatus of claim **2** wherein the coacting means is a pitched means for causing relative forward and rearward motion of the body portions upon rotation of one body portion relative to the other.

5. The apparatus of claim **4** wherein the coacting means are threads.

6. The apparatus of claim **4** wherein the pitched means is a groove in one cylinder wall and a follower extending from the other cylinder wall into the groove.

7. The apparatus of claim **5** wherein the first body portion is slidable into the inside of the second body portion and the coacting means is on the outside periphery of the first body portion and is on the inside periphery of the second body portion.

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